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Description

COOLING SYSTEM FOR A VEHICLE BATTERY

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a system for cooling a vehicle battery.

[0003] 2. Background Art

[0004] There are a variety of vehicles today which utilize electricity, and in particular an electric motor, to at least assist in powering the vehicle. For example, there are electric vehicles, which are powered exclusively by an electric motor; hybrid electric vehicles (HEV), which may be selectively powered by an internal combustion engine or an electric motor; and fuel cell vehicles, or hybrid fuel cell vehicles, just to name a few. The electric motor used in such vehicles may have an electrical power source such as a fuel cell or a battery.

[0005] In the case of a battery used to provide power to an electric motor to drive a vehicle, the temperature of the battery can increase significantly when the motor is used for extended periods of time. The increase in battery temperature may be compounded when the battery is confined to a relatively small, enclosed space. If the increase in battery temperature is left unchecked, the battery life may be reduced. Thus, it is desirable to provide a system for cooling a battery, or batteries, in a vehicle to keep the battery temperature low enough that the battery life is not reduced.

[0006] One attempt to provide cooling to a battery in an electric automobile is described in U.S. Patent No. 5,490,572 issued to Tajiri et al. on February 13, 1996. Tajiri et al. describes a system for cooling a number of batteries in a battery chamber. Air from outside the vehicle may be taken directly into the battery chamber, or the air may first pass through a heat exchanger to cool it before it flows into the battery chamber. Some of the air that flows through the heat exchanger may flow into a vehicle passenger compartment, rather than into the battery chamber.

[0007] Thus, in the system described in Tajiri et al., the same

heat exchanger is used to cool both passenger compartment air and battery compartment air. A number of air discharge ports may be opened or closed to control the flow of air into the passenger compartment; however, the temperature of the air flowing into the passenger compartment will be the same as the temperature of the air flowing into the battery compartment. This is because a single heat exchanger is used to cool the air flowing into both spaces. The air that flows into the battery chamber is discharged outside the vehicle, while the air flowing into the passenger compartment may be discharged outside the vehicle, or recirculated back into the passenger compartment.

[0008] One limitation of the system described in Tajiri et al. is the lack of separate controls for the air flowing into the passenger compartment and the battery compartment. For example, if the temperature of the batteries increases such that the system attempts to provide cool air to the battery compartment, and the temperature of the air outside the vehicle is not low enough to adequately cool the batteries, a damper will be closed to force air through the heat exchanger for cooling, prior to flowing into the battery chamber. If at the same time, the vehicle occupants

request warm air into the passenger compartment, a conflict arises, because there is a single heat exchanger used for both the passenger compartment air and the battery compartment air.

[0009] Another limitation of the system described in Tajiri et al. is the inability to recirculate air within the battery chamber. For example, when the batteries need to be cooled, but the vehicle occupants do not wish to receive air cooled by the heat exchanger, air discharge ports leading into the passenger compartment can be closed. Air cooled by the heat exchanger then passes into the battery compartment; however, there is no mechanism for recirculating the air back through the battery compartment. Instead, it is discharged to the ambient environment outside the vehicle. This may be inefficient, since the cooled air passing through the battery compartment may still be at a lower temperature than the ambient air outside the vehicle. In such a situation, it would be beneficial to recirculate the air from the battery compartment back through the heat exchanger where it could be more efficiently cooled than the outside ambient air. Moreover, recirculating the air may provide the added benefit of reducing the moisture content of the air passing through the heat exchanger.

This could reduce the amount of condensate formed and help prevent icing of the heat exchanger.

[0010] Another system for cooling a battery in a vehicle is described in U.S. Patent No. 5,937,664 issued to Matsuno et al. on August 17, 1999. Matsuno et al. describes a system for cooling a battery, wherein batteries inside a battery chamber are cooled by air taken from the vehicle passenger compartment. After passing through the battery compartment, the air may be recirculated into the passenger compartment, or discharged through an exhaust duct. One limitation of the system described in Matsuno et al. is its reliance on air from the vehicle passenger compartment to cool the batteries. Because the vehicle occupants determine the passenger compartment temperature based on their own comfort level, the air in the passenger compartment may be too warm to adequately cool the batteries. Just as in the system described in Tajiri et al., such a situation presents a conflict between the comfort level of the vehicle occupants and the need to cool the batteries.

[0011] Thus, a need still exists for a system for cooling a vehicle battery that does not rely on passenger compartment air, but rather, can alternatively provide air to cool the batteries taken directly from ambient air outside the vehicle, or

air passed through a heat exchanger separate from a heat exchanger used to cool the passenger compartment air. Moreover, there is also a need for a system for cooling a battery that provides for recirculation of the air from the battery compartment and back through a heat exchanger so as to cool the air more efficiently, and thereby provide an energy savings.

SUMMARY OF INVENTION

[0012] Therefore, a cooling system for a battery in a vehicle having a passenger compartment is provided. The cooling system includes an air intake for receiving air from an ambient environment outside the vehicle. A duct system is capable of providing communication between the air intake and the battery. The duct system is configured to inhibit airflow from the duct system into the vehicle passenger compartment. A fan cooperates with the duct system for moving air through at least a portion of the duct system and across the battery. A heat exchanger cooperates with the duct system and is selectively operable to cool air flowing in the duct system before the flowing air reaches the battery.

[0013] The invention also provides a cooling system for a battery in a vehicle having a passenger compartment. The cooling

system includes an air intake for receiving ambient air from outside the vehicle. A duct system includes first and second duct subsystems. The first duct subsystem is disposed between the air intake and the battery for providing an air flow path from the air intake to the battery. The second duct subsystem is disposed between the battery and the first duct subsystem, and provides an airflow path from the battery to the first duct subsystem. The duct system is configured to selectively inhibit airflow through at least a portion of the first and second duct subsystems. A fan cooperates with the duct system for moving air through at least a portion of the duct system and across the battery. A heat exchanger cooperates with the duct system and is selectively operable to cool air flowing in the duct system before the flowing air reaches the battery.

[0014] The invention further provides a vehicle having a passenger compartment and a battery. The vehicle includes a battery cooling system having an air intake for receiving air from an ambient environment outside the vehicle. A duct system is configured to selectively provide communication between the air intake and the battery, and is further configured to inhibit communication between the passenger compartment and the battery. The battery

cooling system also includes a fan that cooperates with the duct system for moving air through at least a portion of the duct system and across the battery. A heat exchanger cooperates with the duct system and is selectively operable to cool air flowing in the duct system before the flowing air reaches the battery.

BRIEF DESCRIPTION OF DRAWINGS

[0015] Figure 1 is a partial fragmentary isometric view of a vehicle, including a battery cooling system in accordance with the present invention;

[0016] Figure 2 is a partial fragmentary isometric view of a portion of the battery cooling system, including an air intake and a duct system;

[0017] Figure 3 is a side view of the vehicle shown in Figure 1, including a vehicle air intake disposed along an edge of a rear quarter window;

[0018] Figure 4 is a partial fragmentary isometric view of a portion of the battery cooling system, including a pair of fans;

[0019] Figure 5 is a partial fragmentary side view of a portion of the battery cooling system, including a pair of movable baffles;

[0020] Figure 6 is a partial fragmentary isometric view of a por-

tion of the cooling system, including an air extractor;

[0021] Figure 7 is a partial fragmentary isometric view of a portion of the battery cooling system, including a mechanism for moving the movable baffles;

[0022] Figure 8 is a schematic representation of a control system used to control the battery cooling system; and

[0023] Figure 9 is a rear plan view of a vehicle, illustrating the compact nature of the battery cooling system.

DETAILED DESCRIPTION

[0024] Figure 1 shows a cooling system 10 for cooling a battery assembly 12 in a hybrid electric vehicle 14, only a portion of which is shown in Figure 1. Although the hybrid electric vehicle 14 and its battery assembly 12 are used to illustrate the functionality of the cooling system 10, it is understood that a cooling system, such as the cooling system 10, can be effectively used to cool any number of different systems, in any number of different vehicle types. For example, a pure electric vehicle, a fuel cell vehicle, or a hybrid fuel cell vehicle, may also have battery assemblies or other heat generating equipment that require cooling, and would therefore benefit from the use of a cooling system, such as the cooling system 10.

[0025] As best seen in Figure 2, the cooling system 10 includes

an air intake 16 that is configured to receive air from an ambient environment outside the vehicle 14. In the embodiment shown in Figure 2, the air intake 16 of the cooling system 10 is connected to a vehicle air intake 18, which is disposed in a portion of a rear quarter window 20. Figure 3 shows the rear quarter window 20 and a vehicle air intake 18 as viewed from outside the vehicle 14. Of course, a vehicle air intake can be located on other parts of a vehicle; however, having a vehicle air intake, such as the air intake 18, located relatively high-up on a vehicle, may help reduce the intake of water and debris from the road.

[0026] One such air intake is described in copending U.S. patent application, entitled "Fresh Air Intake for a Vehicle", Attorney Docket No. 202-1080, filed on September 12, 2003, and incorporated herein by reference. Locating an air intake high-up on the vehicle can also help avoid water intake if, for example, the vehicle is used to launch a boat. In such situations, a lower portion of the vehicle may become submerged; thus, it may be an added benefit to locate the air intake above the boat launch water line. Such an air intake can also be beneficial for off-road driving.

[0027] Returning to Figure 1, it is seen that the cooling system

10 includes a duct system 22, which, as explained more fully below, can selectively provide communication between the air intake 16 and the battery assembly 12. The duct system 22 is also configured to inhibit airflow between the duct system 22 and a vehicle passenger compartment, for example, passenger compartment 24 shown in Figure 3. Because the cooling system 10 is capable of receiving air from outside the vehicle through the air intake 16, and because the duct system 22 is configured to inhibit airflow to or from the passenger compartment 24, the temperature of the air provided by the cooling system 10 to the battery assembly 12 is independent of the temperature of the passenger compartment 24.

[0028] As illustrated in Figure 4, the cooling system 10 includes a pair of fans 26, 28 which move air through the duct system 22 and across the battery assembly 12. Although the embodiment shown in Figure 4 includes two fans, one fan, or more than two fans, may be used to move the cooling air across the battery assembly 12. The cooling system 10 also includes a heat exchanger, which, in the embodiment shown in Figure 5, is an evaporator coil 30. The evaporator coil 30 cooperates with the duct system 22, and can be selectively operated to cool the air flowing through the

duct system 22 before it reaches the battery assembly 12. A heat exchanger, such as the evaporator coil 30, may be any one of a number of different types of heat exchangers which remove heat from the air flowing through the duct system 22.

[0029] Turning to Figure 5, it is seen that an air filter 31 is disposed in the duct system 22 for filtering the air before it reaches the evaporator coil 30. In the embodiment shown in Figure 5, the evaporator coil 30 is part of an air conditioning system. Such an air conditioning system may have more than one evaporator coil in the same system to cool different spaces within a vehicle. One such cooling system is described in copending U.S. patent application, entitled "Vehicle Cooling System", Attorney Docket No. 202-1623, filed on September 12, 2003, and incorporated herein by reference.

[0030] The evaporator coil 30, shown in Figure 5, receives a refrigerant through a refrigeration line 32 when the ambient air outside the vehicle is too warm to adequately cool the battery assembly 12. Refrigerant in the refrigeration line 32 flows through a thermal expansion valve 34 prior to reaching the evaporator coil 30. Because condensation may occur as air flows through the evaporator coil 30, the

cooling system 10 is provided with a drain line 36 to allow condensate to leave the duct system 22. A check valve 38 provides for one way flow, such that unfiltered air will not rise back into the duct system 22. A second drain line 39 is in communication with the vehicle air intake 18, for draining water that may be taken in from the ambient air outside the vehicle.

[0031] Also shown in Figure 5 is a thermistor 41 configured to monitor the air temperature adjacent the evaporator coil 30. If the thermistor 41 senses a temperature that is below a predetermined temperature, the flow of refrigerant through the evaporator coil 30 is stopped. This prevents the undesirable build-up of ice on the evaporator coil 30.

[0032] Returning to Figure 2, it is seen that the duct system 22 includes first, second and third duct subsystems 40, 42 and 44, respectively. The first duct subsystem 40 is disposed between the air intake 16 and the battery assembly 12, and provides an airflow path from the air intake 16 through the evaporator coil 30 and to the battery assembly 12. The second duct subsystem 42 is disposed between the battery assembly 12 and the first duct subsystem 40. The second duct subsystem 42 provides for recirculation of air from the battery assembly 12 back through

the evaporator coil 30, and back to the battery assembly 12.

[0033] Recirculation of air in this manner is particularly useful when the ambient air outside the vehicle is too warm to adequately cool the battery assembly 12. Indeed, the temperature of the air flowing from the battery through the second duct subsystem 42 may still be significantly lower than the temperature of the ambient air outside the vehicle. In such cases, it is more efficient to further cool this air by passing it through the evaporator coil 30, rather than cooling the ambient air taken in through the air intake 16.

[0034] Another benefit to using the recirculating air, is that it may have a significantly lower moisture content than fresh air taken in from outside the vehicle. Thus, less condensate will form as the recirculating air passes through the evaporator coil 30. This also helps prevent icing of the evaporator coil 30. When the ambient air temperature outside the vehicle is low enough to adequately cool the battery assembly 12, the flow of refrigerant to the evaporator coil 30 can be stopped, and ambient air taken from outside the vehicle can be directly provided to the battery assembly 12. In such a case, the third duct subsystem 44

may be used to provide an airflow path from the duct system 22 to the ambient environment outside the vehicle 14 through an air outlet, or air extractor 46.

[0035] Figure 6 shows the air extractor 46 attached to the third duct subsystem 44. The air extractor 46 includes an upper portion 48 and a lower portion 50, both of which provide an outlet to the ambient environment outside the vehicle. The third duct subsystem 44 connects to the upper portion 48 of the air extractor 46. Although it is not shown in Figure 6, the lower portion 50 may be connected to a duct, or series of ducts, that provide an airflow path from the passenger compartment 24. A flow inhibitor 52 is included in the lower portion 50 for inhibiting the flow of air from the third duct subsystem 44 through the air extractor 46, and back into the vehicle passenger compartment 24.

[0036] In the embodiment shown in Figure 6, the flow inhibitor 52 is an approximately vertically oriented flap, pivotally attached to the air extractor 46, such that air flowing out of the third duct subsystem 44 tends to be expelled into the ambient environment outside the vehicle 14, rather than back into the passenger compartment 24. Even if some air does flow back into the vehicle passenger com-

partment 24, however, the volume of this back flow air would be negligible. Of course, other types of flow inhibitors may be used to inhibit the flow of air from the duct system 22 into the vehicle passenger compartment 24.

[0037] As best seen in Figure 5, the duct system 22 includes first and second baffles 54, 56. The first baffle 54 is movable between a first position and a second position, shown in Figure 5 by the numbers 1 and 2, respectively. When the first baffle 54 is in the first position, it facilitates airflow from the air intake 16 to the battery assembly 12 through the first duct subsystem 40. In the second position, the first baffle 54 facilitates airflow from the battery assembly 12 back to the first duct subsystem 40, through the second duct subsystem 42. This facilitates recirculation of air across the battery assembly 12, while at the same time, inhibiting the flow of air from the air intake 16 to the battery assembly 12.

[0038] The first baffle 54 is also movable to an intermediate position, designated in Figure 5 by the number 3. While in the intermediate position, the first baffle 54 facilitates airflow from the air intake 16 to the battery assembly 12 through the first duct subsystem 40, and at the same

time, facilitates the recirculation of air from the battery assembly 12 through the second duct subsystem 42, and back to the battery assembly 12.

[0039] The second baffle 56 is also movable between first, second and intermediate positions. The second baffle 56 can be placed in the first position to facilitate airflow through the third duct subsystem 44 and out of the air extractor 46 to the ambient environment outside the vehicle 14. This position may be used when ambient air is drawn in through the air intake 16, and the cooling system 10 is not in a recirculation mode. Conversely, the second baffle 56 can be placed in a second position, which inhibits airflow through the third duct subsystem 44, and facilitates recirculation of air from the battery assembly 12, through the evaporator coil 30, and back to the battery assembly 12. The second baffle 56 is also movable to an intermediate position, as shown in Figure 5, wherein some of the air flowing through the second duct subsystem 42 is diverted back to the battery assembly 12 for recirculation, while some of the air is routed through the third duct subsystem 44, and expelled through the air extractor 46.

[0040] When the first baffle 54 is in the first position, it will often be desirable to have the second baffle 56 also in the first

position. This facilitates the intake of fresh air through the air intake 16 to cool the battery assembly 12, and the expulsion of the air from the vehicle 14 through the air extractor 46. Similarly, when the first baffle 54 is in the second position, it will often be desirable to have the second baffle 56 in the second position. This facilitates recirculation of air from the battery assembly 12 through the evaporator coil 30, and back to the battery assembly 12. As discussed above, such an arrangement may be more energy efficient than cooling the air taken in from the ambient environment outside the vehicle. In order to facilitate synchronous operation of the first and second baffles 54, 56, the cooling system 10 includes a mechanical linkage 58, shown in Figure 7, that connects lever arms 60, 62, which can be used to move the baffles 54, 56 to and from different positions. An electric actuator 64 is provided for moving the baffles 54, 56 to their desired positions.

[0041] In order to control the electric actuator 64, as well as other elements of the cooling system 10, a controller, such as a powertrain control module (PCM)66, shown in Figure 8, may be used. Figure 8 illustrates a simple schematic control system for the cooling system 10. The

PCM 66 is connected to the cooling system 10, and to a number of inputs, in particular temperature sensors 68, 70. The first temperature sensor 68 is configured to measure a temperature indicative of the temperature of the ambient environment outside the vehicle. For example, the temperature sensor 68 may be positioned such that the temperature of the ambient air outside the vehicle is directly measured.

[0042] Alternatively, the temperature sensor 68 could be a mass air temperature sensor commonly used in vehicle engine systems. In such a case, the temperature sensor 68 would not directly measure the temperature of the ambient air outside the vehicle. Rather, the temperature sensor 68 would measure the temperature of the air within the engine system, and a controller, such as the PCM 66, would use a preprogrammed algorithm, such as a lookup table, to correlate the measured temperature with the temperature of the ambient air outside the vehicle. Thus, the PCM 66 is provided with information from the temperature sensor 68 that allows the temperature of the ambient air outside the vehicle to be used by the PCM 66 in controlling the cooling system 10.

[0043] Similarly, the temperature sensor 70 measures a tempera-

ture that is indicative of the temperature of the battery 12, and sends a signal related to the measured temperature to the PCM 66. A temperature sensor, such as the temperature sensor 70, may directly measure the temperature of one or more of the battery cells in the battery assembly 12. Alternatively, a temperature sensor may be used to measure the temperature of the ambient air directly surrounding the battery assembly 12. Thus, the PCM 66 can use both the temperature of the ambient air outside the vehicle and the temperature of the battery assembly 12 to help control the cooling system 10.

[0044] The PCM 66 is configured to control the various elements of the cooling system 10, such as the operation of the fans 26, 28, the flow of refrigerant to the heat exchanger 30, and the movement of the first and second baffles 54, 56. Of course, a single controller, such as the PCM 66, which may be used to control a wide variety of powertrain systems, does not need to be used to directly control a cooling system, such as the cooling system 10. For example, the cooling system 10 may have a separate controller, configured to communicate with a PCM, and to receive signals such as those output by the temperature sensor 70. In addition, the battery assembly 12, may have its own

traction battery control module (TBCM) that communicates with a separate cooling system controller and/or a PCM. Thus, there are any number of ways to control a cooling system, such as the cooling system 10, with the one illustrated in Figure 8 providing but one example.

[0045] The cooling system 10 can also be conveniently packaged to fit in a vehicle without unduly limiting the space available for passengers and cargo. For example, Figure 9 shows the rear portion of the vehicle 14 having a rear vehicle opening 72. Typically, a rear vehicle opening, such as the opening 72, will be covered by a tailgate and a back light, which have been removed from this view for clarity. As shown schematically in Figure 9, the cooling system 10 includes a first portion 74, and a second portion 76. The first portion 74 is adjacent the rear vehicle opening 72, and it is configured to provide substantially uninhibited access to the passenger compartment 24 through the opening 72.

[0046] In the embodiment shown in Figure 9, the first portion 74 does not extend beyond an edge 78 of the rear vehicle opening 72. Of course, different styles of vehicles may require the first portion 74 to extend slightly beyond the edge of 78 of the rear vehicle opening 72; however, ac-

cess to the passenger compartment 24 can still be substantially uninhibited. This provides convenient access to and from the passenger compartment 24 through the rear vehicle opening 72, without encountering interference from a cooling system that extends substantially beyond an edge of a rear vehicle opening, such as the opening 72.

[0047] Similarly, the second portion 76 of the cooling system 10 is disposed beneath a load floor 80, and is adjacent the battery assembly 12. The second portion 76 maintains a low profile, such that the load floor 80 can remain substantially level throughout the rear portion of the vehicle 14. This provides for use of the load floor 80 without interference from raised portions which may be inconvenient for passengers and cargo storage alike. Thus, the cooling system 10 serves the important function of cooling a battery or battery assembly, with little or no sacrifice of the space in the vehicle interior.

[0048] While the best mode for carrying out the invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.